

Orbit Databases and Fast Gravity Fields for Rapid Trajectory Design Near Small Bodies

Completed Technology Project (2016 - 2020)



Project Introduction

Scientific and engineering interest has recently significantly shifted beyond the large planets and moons, which gravitationally dominate their respective localities, to the smaller, irregularly shaped, comets and asteroids roaming the solar system around us. Due to the multi-body dynamics and highly non-spherical gravity fields common to small bodies, state-of-the-art trajectory design and re-design around small bodies can be a slow, ground-based process requiring significant input from specialists. At the same time, the smaller scales and vast number of asteroids and comets often requires rapid recalculation of orbits and trajectories. Part of the solution to these conflicting realities is the fundamental ability to rapidly design trajectories around small bodies. By applying and enhancing fast gravity field techniques, implementing grid searches and root solvers to find useful periodic and quasi-periodic orbits, the proposed research aims to create and innovatively use a new catalogue of trajectories around small bodies of interest to enable rapid trajectory design in those environments. Though there has been extensive research into various methods of generating gravity fields for small, irregularly shaped bodies, these methods have not yet been applied to a large set of mission candidate bodies in varied dynamical environments, nor have they been adapted or enhanced to suit the needs of the rapid trajectory design problem at small bodies. Among these are: 1) Adaptive computation of the potential field must be fast and efficient enough to allow rapid exploration of the trajectory design space, science instrument and experiment simulations, and in-mission trajectory re-design; and, 2) Acceleration values must adhere closely enough to reality to provide accurate trajectories, even in the presence of dynamics uncertainty and the need for rigorous Monte Carlo simulations. Therefore, the research team seeks to study alternative ideas for basis functions and interpolation techniques, and implement the best solution for a broad set of small bodies of interest. The research team will also investigate interpolated gravity fields for the particular case of onboard use, since the spacecraft only requires a small local field representation to be stored onboard. To achieve speedups in field calculation and trajectory design times, modern parallel computing techniques and uncertainty quantification analysis will be leveraged. Modern small-body orbit and trajectory design methods do not typically include higher-order shape irregularities in their dynamical models, nor do studies developing more detailed gravity field models conduct comprehensive orbit and trajectory searches using those models. To address both of these issues, the research team plans to conduct an exhaustive search for stable orbits and trajectories around a wide set of candidate small bodies, taking advantage of the implementation of the fast accurate gravity field calculation developed in the first objective. The purpose of this orbit archive will be to ease the rapid trajectory design and optimization processes on the ground and onboard a spacecraft by providing a large set of good initial guesses for targeted trajectories. This archive of orbits (analogous to Keplerian orbits in the two body problem), will also provide options for science orbits, and transfers between science orbits. By extending the topics of fast accurate gravity field



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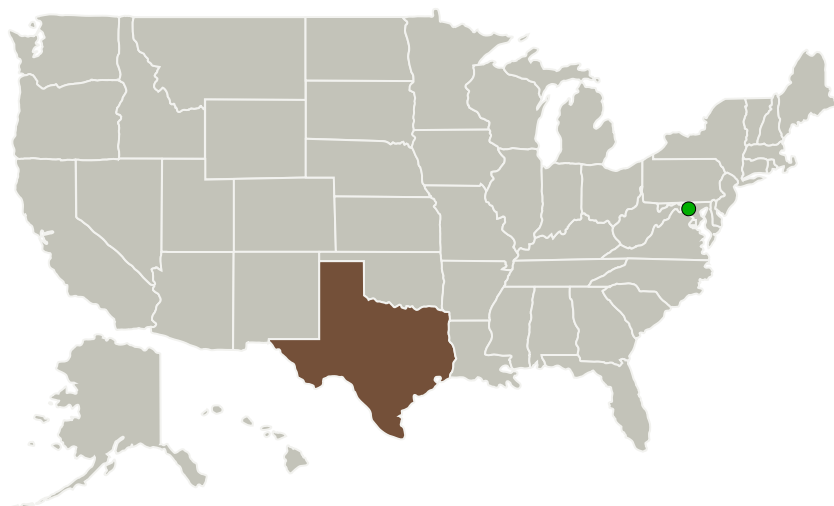


modeling and rapid small-body trajectory design and coupling the interactions between them in a catalogue of stable orbits and trajectories around real small bodies, the proposed research will expand and enable more rapid and thorough searches of the orbit design space around small bodies. This innovation is an important step toward lowering NASA mission costs because it allows pre- and post-launch quick redesigns of trajectories, as well as faster evaluation of trade-offs between proposed mission scenarios.

Anticipated Benefits

By extending the topics of fast accurate gravity field modeling and rapid small-body trajectory design and coupling the interactions between them in a catalogue of stable orbits and trajectories around real small bodies, the proposed research will expand and enable more rapid and thorough searches of the orbit design space around small bodies. This innovation is an important step toward lowering NASA mission costs because it allows pre- and post-launch quick redesigns of trajectories, as well as faster evaluation of trade-offs between proposed mission scenarios.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

The University of Texas at Austin

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Ryan P Russell

Co-Investigator:

Patrick Wittick

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Organizations Performing Work	Role	Type	Location
The University of Texas at Austin	Lead Organization	Academia	Austin, Texas
● Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland

Primary U.S. Work Locations

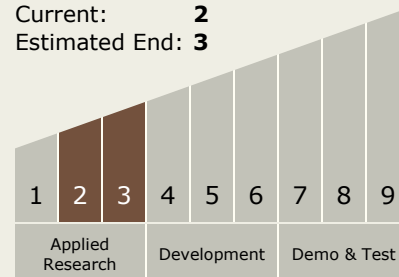
Texas

Project Website:

<https://www.nasa.gov/strg#.VQb6T0jJzyE>

Technology Maturity (TRL)

Start: **2**
 Current: **2**
 Estimated End: **3**



Technology Areas

Primary:

- TX17 Guidance, Navigation, and Control (GN&C)
 - └ TX17.2 Navigation Technologies
 - └ TX17.2.6 Rendezvous, Proximity Operations, and Capture Trajectory Design and Orbit Determination

Target Destination

Others Inside the Solar System